

PIP PIN RELIABILITY AND DESIGN

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ABSTRACT

Pip pins are used in many engineering applications. Of particular interest to the aerospace industry is their use in various mechanism designs. Many payloads that fly aboard our nation's Space Shuttle have at least one actuated mechanism. Often these mechanisms incorporate pip pins in their design in order to fasten interfacing parts or joints. Pip pins are most often used when an astronaut will have a direct interface with the mechanism. This interfacing can be done during Space Shuttle mission EVAs (Extra Vehicular Activities). The main reason for incorporating pip pins is convenience and their ability to provide quick release of interfacing parts. However, there are some issues that must be taken into account when using them in a design. These issues include documented failures and quality control problems when using substandard pip pins. A history of pip pins as they relate to the aerospace industry as well as general reliable design features is discussed.

INTRODUCTION

Pip pins are a logical choice in a design that requires expedient release of joints of interfacing parts. Shear loads are most often present in these interfacing joints, however, pip pins can be designed to react tensile loads. Although they are efficient and effective in utilization, there are several aspects to consider when incorporating a pip pin into a design. Several failures have occurred during NASA vibration and thermal/vacuum testing of past flight projects. Due to these failures, general design considerations of pip pins have been scrutinized and reconsidered to alleviate inherent problems with previous designs. As a result, new techniques in the design and fabrication of pip pins have been developed to create a more reliable pip pin.

HISTORY

The name pip pin is a short abbreviation of "push in and pull" pin.

Although several documented inadvertent releases of pip pins have been noted, no serious documented failures occurred in our nation's space program until 1990. During this year, NASA began environmental testing of the EVA Development Flight Experiments (EDFE) payload. During vibration testing, several locking balls in the pip pins vibrated out of their sockets. In addition, the lubricant inside of the pins froze and seized the pins during cold temperature vacuum testing. NASA solved these problems by using Military Standard pip pins that were quality controlled and removed all lubrication from the pip pins. Since the EDFE pip pins would be used for only one mission, and lubrication was mainly provided for corrosion protection, it was decided that the lubrication was not needed.

Although NASA/JSC had previously proposed improvements in pip pin designs, as a result of the EDFE project, JSC began working on additional design solutions to make all pip pins more reliable. Several design changes were made to existing pip pins as a result of this process in order to generate "space" quality products.

DESIGNS

It should be noted that the improvements made to the general design of pip pins were dictated by NASA to create more reliable pip pins for our nation's space program. Design changes were made specifically for space applications. There are no other designs (vendor or Military Specification) known that are specifically for space applications. Design improvements made are as follows (Figure 1 details these design features):

Four Locking Balls

Four locking balls are utilized in all of the new designs. Incorporating four balls provides redundancy if one of the balls falls out of its socket. Designs with two locking balls are not redundant, if one ball falls out, the inner shaft becomes loose and the remaining ball may no longer be in contact with the internal shaft. This loose fit may then vibrate to the point causing the remaining ball to fall into the inner

shaft ball groove or fall out of the barrel end of the pin. With the four ball design, if one ball falls out of its socket, the inner shaft will be retained by the remaining three balls.

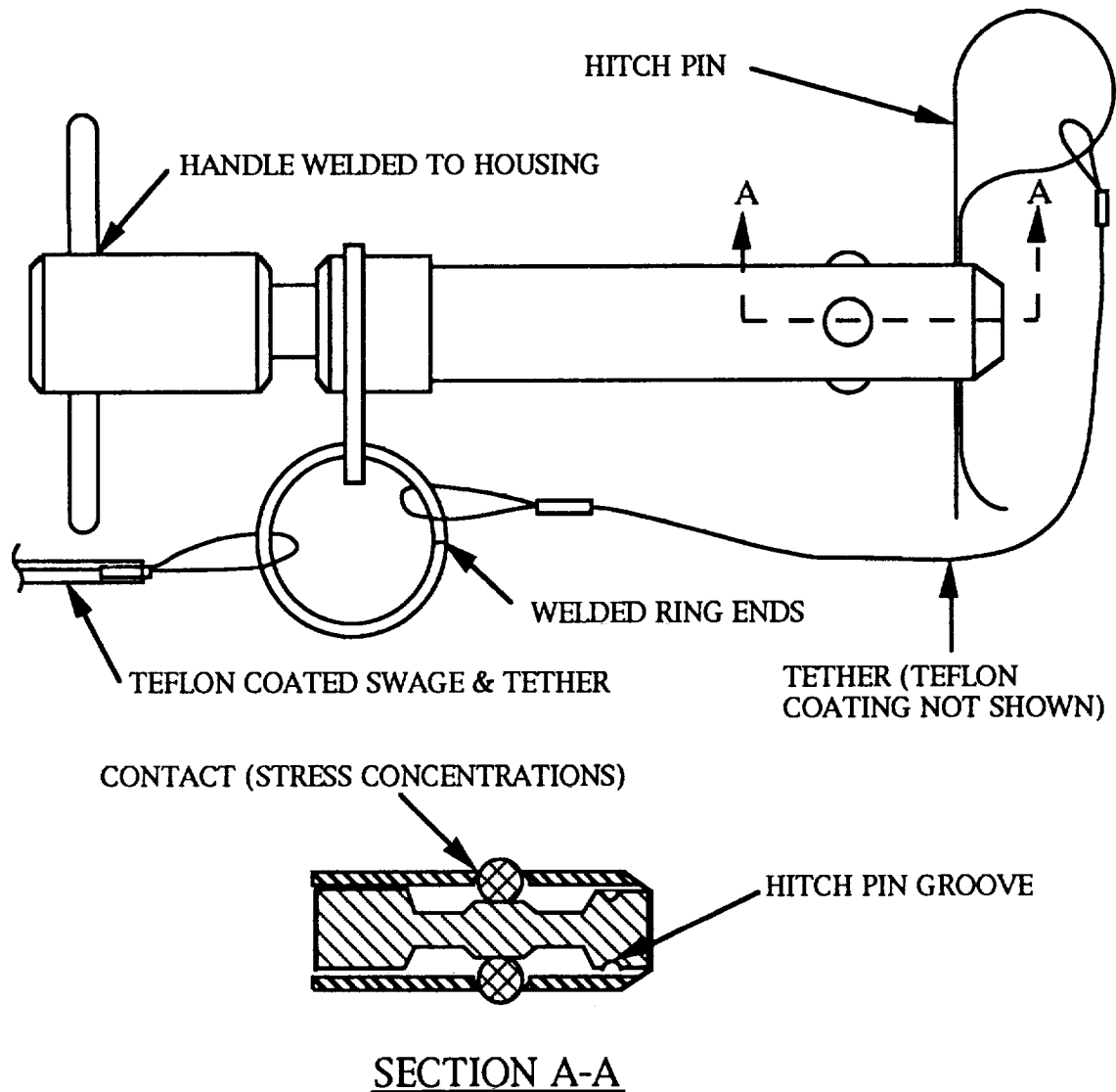


Figure 1. Pip Pin Schematic (T-Handle, Double Acting)

Double Acting

Most single acting pip pins only provide release capability when a spring loaded release button on the handle is pushed. Referring to

Section A-A of Figure 1, the double acting pip pins provide release capability when the handle is either pushed or pulled. Grooves are cut in the inner shaft on both sides of the locking balls to provide this capability. The benefit from providing this capability is that the pin is more ergonomically compatible. It provides more efficient and effective removal from and insertion into mating pip pin holes.

Teflon Coated Tethers

When wire tethers are swaged onto tether rings, the possibility exists that the wire end may protrude beyond the swaged fitting. This would create a tear hazard for an astronaut's pressure suit. Therefore, a Teflon sleeve was added to cover the swage fitting & cable termination. A Teflon coating on the cable provides a smooth surface on the outside of the tether thereby preventing the possibility that the astronaut's suit will come into contact with any frayed or broken cable strands.

Welded Handle and Tether Ring

In many pip pin designs, handles are pinned into place with a dowel pin. This oversized fit between the dowel pin and dowel hole provides fastening of the handle onto the head of the pip pin. This presents failure scenarios of the dowel pin shearing or working out of the hole due to vibration or thermal effects. These failure scenarios were corrected by welding a one piece handle to the head of the pip pins, providing assurance that the handle will not easily separate from the pip pin head.

Tether rings are critical in preventing the pip pin from floating away in a zero gravity environment. Therefore, a reliable tether attachment is essential. In order to provide the most dependable tether arrangement, all tether rings are either solid or have welded ends. When a ring is not created as a one piece solid, there will be two ends of the ring that will come together. These ends are welded to increase reliability. Split rings (such as a key chain ring) were considered hazardous because of two reasons: 1) an accidental release could occur due to the tether working itself between the ring splits, and 2) because an astronaut could tear a glove on the sharp tip edges where the splits begin and end.

Ball Staking

Present fabrication techniques for installing locking balls into their respective sockets involves a method called staking. This technique consists of first dropping the ball into its socket. Then a punch is used to deform the virgin material at the top edge of the hole. In doing this, the material deforms around the ball to reduce the diameter of the opening which should keep the ball in its socket.

There are several problems with this method. The actual staking is a crude operation. There is a large amount of room for error when a technician conducts this operation. Inspections have shown that, on several occasions, all of the expected material was not staked into the hole. This results in the ball not being completely retained in the socket, allowing it to fall out during certain loading applications. Another problem with staking appeared during vibration testing. Tests have shown that, occasionally, the staked material is relatively thin & that stress concentrations can be created at the tip of the staked material. During vibration these thin areas may fracture as a result of high stress concentrations. Once the material fails, the locking ball could fall out creating a hazard.

On-going research and development techniques are being studied on how to alleviate the problem of staking. Techniques to create the ball socket without staking are being considered. One possibility includes creating a tapered socket from the inside of the pin barrel by the use of Electronic Discharge Machining (EDM). If the proper socket can be created, the balls could be installed from the barrel end of the pin with no staking or deforming operations required.

Lubrication

Dry film lubricants are now being used to lubricate all internal parts of the pip pins. The problem of an organic grease or oil freezing, which can seize a pin, is corrected by using a dry film lube. In addition, the dry film lube will not collect and trap contaminants like a grease or oil would. Trapping contaminants creates another possibility that the pip pin will seize.

Hitch Pins

One area of pip pin design that has created some controversy is the use of hitch pins to ensure the pip pins are not inadvertently removed or disengaged. Hitch pins are a highly reliable design feature to incorporate into a pip pin design. The hitch pins manually secure the ball activation spindle, locking the balls into the locked position. Even if all locking balls are lost from the pip pin, the pin will remain installed until the hitch pin is removed.

Hitch pins are ideal for secure or high reliability applications where the pip pin only has to be removed and not re-installed. Re-installation of a hitch pin is difficult due to the small diameter hole the hitch pin has to be inserted into. The possibility also exists that hitch pins present a snag hazard for the astronauts' pressure suit. Any snag condition to a space suit could result in a catastrophic hazard.

Summary

Pip pins are very useful in many aerospace mechanism applications. When they are utilized, several design and fabrication features should be considered in selecting a proper pin. If the pin is in a critical location and a substandard pin is selected, a catastrophic failure of the mechanism could result. Several design features to be considered when selecting or designing the pins are; 1) the use of four locking balls, 2) providing a double acting engagement/disengagement feature, 3) provision of Teflon coated tethers, 4) welded handles and tether rings, 5) locking ball installation procedures, 6) choosing the correct lubrication, and 7) the use of hitch pins. The selection of the proper pip pin could be the difference between a successful mission and a catastrophic hazard.

ACKNOWLEDGEMENTS

The author would like to thank W. B. Wood (NASA/JSC), Gary Krch (ILC/JSC), and Robert Stondell (Space-Lok Inc./Burbank, CA) for their input on the design process of the new techniques developed for pip pins. He would also like to thank John Zipay (NASA/JSC) for providing a history of pip pins as they relate to our nation's space program. Carolyn Ricaldi (Lockheed/JSC) should also be acknowledged for her help in putting this paper together.